CIE Independent Peer Review Report of:

Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem

Alaska Fisheries Science Center
Seattle Washington
July 21-24, 2015

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1. Executive summary

The meeting to review the Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem was held in Alaska Fisheries Science Center, Seattle, Washington, from 21 to 24 of July 2015.

The quality of the work presented at this review was impressive, the program has developed into a well-coordinated approach under the RPA and is bringing together all the tools to build an understanding of recruitment processes for walleye pollock; mechanistic understanding of recruitment is the holy grail of fisheries science. This program is now more complete and better focused than any other program in recruitment processes that I am aware of.

The co-located sampling of physical, planktonic and larval fish stages in the spring is of considerable importance for current and potential modelling development.

Where possible, the spring survey grid should be designed to capture the full population ranges of the species of interest, ensuring that model comparison and inference can be related to population level. The young of the year (YoY) surveys in the late summer should also continue with co-located sampling to determine the population level status, size, condition and location as the yearclass enters the winter.

Due to differences in sampling area coverage and utility, it is preferable to separate the salmon survey from the surveys of recruitment for walleye pollock, Pacific cod and arrowtooth flounder, if resources permit.

The major contribution of this work so far has been the coupling of recruitment processes to climate in a way to give medium term forecast projections. For the future, biennial surveys are probably adequate for general ecosystem stories and provision of indicators for IEA. Annual surveys would greatly speed up the process of both mechanistic/IBM model based recruitment indicators. Also, annual surveys would be much better placed to give O group or improved 1 group indexes of walleye pollock for use in the assessment.

The major gap in the information currently being collected is data to explicitly confirm the extent to which it is the summer or winter mortality that is the primary mechanism for determining yearclass strength for walleye pollock. Improved late summer YoY surveys will help with this issue. However, survey solutions to assess through the winter mortality appear to be limited, but there may be some benefit in attempting to obtain samples of O group walleye pollock through the winter for analysis of size distribution and energetics, to track growth/mortality to the 1 group survey the following year.

For the provision of good salmon bycatch prediction there is a need to test the relationships between Upper Yukon returns and total Chinook salmon bycatch and to estimate if the precision of this regression provides a basis for advice for the whole area. If extending the index to all bycatch improves the prediction of bycatch impact rate over the current methodology then it would be useful to evaluate if more precision is needed to ensure bycatch limits are neither unnecessarily restrictive nor lax. If more precision is needed, then an extension of the northeastern Bering Sea (NEBS) salmon survey to the southeastern Bering Sea (SEBS) coast area would be the next step.

2. Background

The ecosystem and fisheries recruitment processes applied research conducted at the NMFS's Alaska Fisheries Science Center (AFSC) is coordinated under the Recruitment Processes Alliance (RPA), and the survey work of this group is the subject of this review. Ecosystem and fisheries research has been conducted by various programs within the AFSC for over 30 years. Recently, several of these programs came together to form the RPA, with the aim of joining expertise and effort to facilitate scientific exchange in the study of Arctic and North Pacific ecosystem functioning. The RPA, comprises elements from the Recruitment Processes program (the Ecosystems and Fisheries Oceanography Coordinated Investigations or EcoFOCI), the Ecosystem Monitoring and Assessment (EMA) program (the Bering Arctic-Subarctic Integrated Survey or BASIS), the Marine Acoustics and Conservation Engineering (MACE) program, the Resource Ecology and Ecosystems Modeling (REEM) program, and the Resource Energetics and Costal Assessment (RECA) program, as well as the members of the EcoFOCI Program that reside at the Pacific Marine Environmental Laboratory (PMEL). This effort is a unique collaboration among NMFS programs within the AFSC and across-line offices (National Marine Fisheries Service and Oceanic and Atmospheric) with a primary goal to provide mechanistic understanding of the factors that influence recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing the first year of ocean life. To accomplish these objectives, seasonal (spring, summer, autumn) field surveys and process-oriented research are conducted to inform single-species, multi-species, and biophysical ecosystem models. Survey methods rely on gridded net tows and selected use of acoustics to collect target species, with concurrent oceanographic and environmental sampling to estimate biological and physical oceanographic structuring forces. The review focused on the survey methodology and analytical approaches used to estimate relative abundance, distribution, biomass, and physiological condition of target species, the biophysical environmental variables thought to structure recruitment of target species, and the incorporation of observed variables into ecosystem forecast models, Integrated Ecosystem Assessments (IEAs), and Ecosystem Based Fishery Management (EBFM) practices. The Terms of Reference (ToRs) of the peer review are attached in Annex 2 to Appendix 2. The agenda of the panel review meeting is attached in Annex 3 to Appendix 2 and the participants' list is in Appendix 3.

3. Description of the reviewer's role in the review activities

I participated in all aspects of the review, paying particular attention to: the survey design options and the issues surrounding salmon bycatch information from surveys.

4. Findings by ToR

The report is organized following the 8 Terms of Reference listed in Annex 2 to Appendix 2. For coherence of discussion ToR 1 and 2, and Tor 3 and 4 have been combined in sections 4.1 and 4.2 respectively. ToRs 5 to 8 are dealt with individually in sections 4.3 to 4.6. The agenda for the meeting and the list of participants who attended the review are given in Appendix 3.

4.1. Review of background materials and historic spring and late summer ecosystem and fishery survey

ToR 1: Review background materials and documents that detail the ecosystem and fishery survey design and methods, and data analysis methods and results for:

a. Joint walleye pollock, Pacific cod, and arrowtooth flounder surveys;
b. Chinook salmon and chum salmon survey
c. Joint bio-physical oceanographic survey component (ecosystem).

Tor 2: Evaluate the historic, spring and late summer ecosystem and fishery survey designs, methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

Documentation

The documentation provided was based on a number of background papers and reports most of which were supplied shortly before the start of the review meeting, these are listed in Appendix 1. In addition, the review was supplied with a series of presentations, based largely on these papers. Most of the presentations were related to the use of the survey data, the details of the analyses methods and modeling were provided at a generally level. This allowed a clear idea of the analytical approaches used along with the uses of the surveys, but did not allow evaluation of details of the calculation procedures. The modelling framework was well described conceptually but not in full detail. Nevertheless as many of the procedures had been used to support peer reviewed scientific papers, there is no reason to consider that there are any specific analysis issues.

Four main surveys were presented, two of these were designed primarily to service four multi-instrumented hydrographic moorings. From the presentations it was anticipated that these were to remain unchanged. The other two surveys, one in the spring and one in the fall were described as a ‘spring larval survey’ and a late summer young of the year survey respectively. Both surveys have a major component of physical and biological oceanographic data collection in addition to the fish sampling. These surveys are considered in turn below.

Overview of oceanographic drivers

To give an understanding of the basis of the survey discussion a brief description of the oceanographic system is included here, this is based on a number of papers, the best synthesis being provided by Duffy-Anderson, J.T. *et al.* (2015) and a draft paper Sigler *et al.* (2015). On an annual basis wind resulting from the locations of atmospheric high and low pressure systems drive the ice southwards and westwards and the strength and direction of this wind determines ice coverage for the first months of each year. The extent of the ice coverage into the southeastern Bering Sea (SEBS) determines the kind of year (warmer or colder). As the ice melts at the end of the winter the fresher meltwater can form a cold pool in areas previously covered by ice, which increases the likelihood of sustained stratification, which can change the timing and quality of the spring bloom.

In this system, the type of available food (more or less lipid) is dependent of the type of year, with higher lipid food occurring in colder years, this is thought to be more effective in providing growth for walleye pollock. Observations on diet (Heinz *et al.* 2013 and Gann *et al.* 2015) indicate that this food source may determine survival for walleye pollock. It is thought that larger pollock with higher lipid feed will have a higher probability of surviving through the subsequent winter, giving rise to more numerous year classes. This relationship has been observed also for cod in the past giving some synchronicity with cod and walleye pollock recruitment. However, in recent years, cod recruitment has varied independently of walleye pollock recruitment suggesting that additional factors are also involved.

In some years it has been observed that distributions of 0 group walleye pollock does not always end up in the best feeding areas (Siddon *et al.* 2013). Though changes in temperature may influence the timing of spawning the location of spawning appears more stable over years (Smart *et al.* 2012). Temperature also influences the overlap between adult walleye pollock and young of the year (YoY).

In conclusion, the variability of the physical processes influences both location timing and magnitude of O group fish particularly in the spring. This variability needs to be taken into account in the survey design.

Mooring service surveys (spring and fall)

These surveys involve visiting the four mooring sites, but they are also used to collect additional biological and physical data from a series of stations along the isobath that links the moorings and a number of across shelf transects (Stabeno 2012). Substantially higher data collection station density is applied along shelf than across shelf. However, from the data shown it appears that the spatial autocorrelation along shelf may not be much different from the autocorrelation across shelf. It may be worth examining the autocorrelation across the data types and years to consider if more overall useful information can be obtained with increased station allocation across shelf with reduced along shelf data. It may be possible that redistribution of effort between these directions may use the available survey time to better effect. The maximum amount of information is collected if the along and across shelf spacing are placed as the same 'value' of autocorrelation in both directions, the value chosen will be different for different variables (i.e. at such a spacing, the potential change in information between stations is expected to be similar in both directions). As it is not intended to modify these surveys in a major way, they will not be discussed further.

Spring Larval survey

The historic information on spawning areas has identified a small number of major centers of spawning for cod, walleye pollock and arrowtooth flounder south of 60N, with most of the spawning near the shelf edge. The dominant larval drift is in either the 'on shelf' or a northwards direction. As discussed above, the timing and location of spawning are both expected to be different among years and this needs to be considered in the design of the spring larval survey.

The chosen strategy is a regular evenly spaced grid based on a fixed starting point. This has the property that in theory it provides the most precise estimate of an index of abundance, for the area of the domain surveyed. A regular grid is also more suitable for spatial mapping. A survey grid would require a random start point (on the scale of the spacing) to be formally used to estimate total abundance. Though in practice, such a requirement has only a minor influence on the use of a fixed grid for abundance estimation. A regular grid is also the most suitable strategy for providing comparison with gridded model output. Some of these design issues are discussed in the context of estimation of indices in by a survey design workshop (see for example ICES 2005).

On occasions it may be necessary to estimate the uncertainty or variance of the estimated parameters from the regular grid sampling. Because the grid is a regular variance estimation will necessarily need to account for spatial autocorrelation. For this survey variance estimation may also be made more complex due to varying timing of spawning coupled to varying drift among years. There are, however, geostatistical transitive methods that are specifically adapted for regular grid sampling, see for example Rivoirard *et al.* (2000) and Petigas (2001) for an introduction to these methods.

The survey grid has developed over several years changing from 2010 to 2011, and has been extended from the initial station layout. However, despite modification, it still appears to be prone to boundary issues, where high values are encountered on the edges of the sampling grid and some uncertainty remains in determining the northern boundary (Figure 1). Given the very dynamic nature of both timing and extent of larval distribution a fixed grid is not currently delivering high quality coverage. The plots provided as examples indicate a fairly high level of autocorrelation.

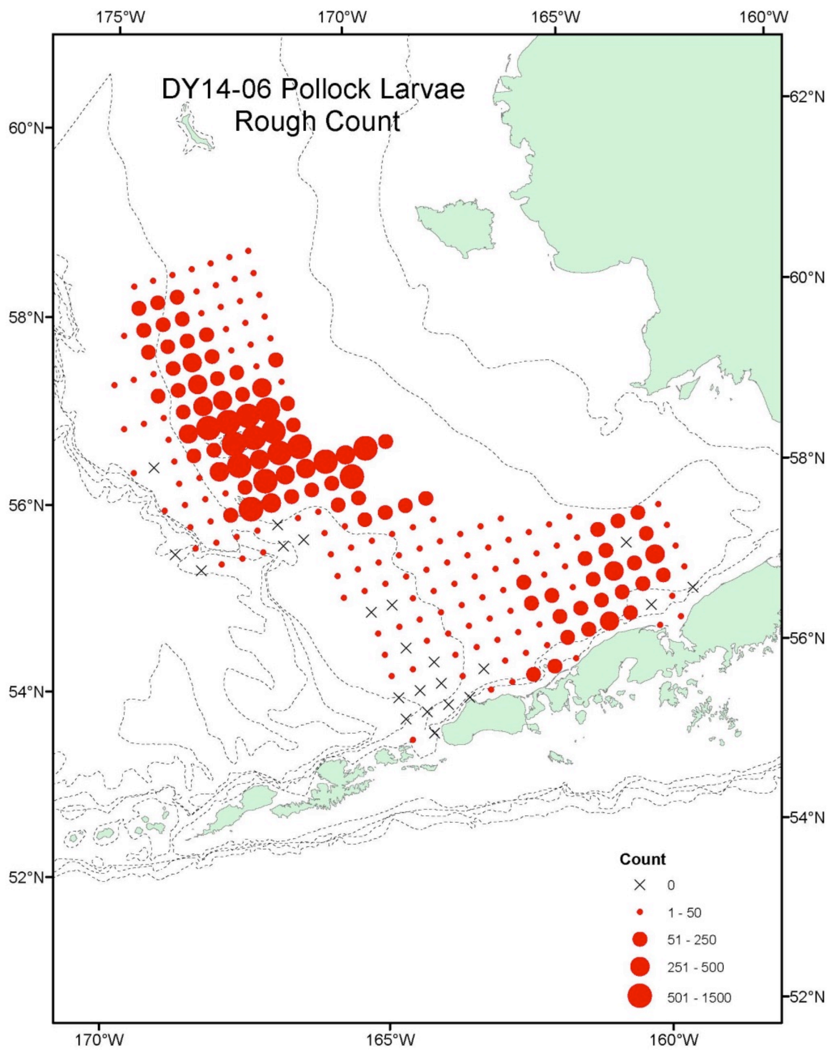

Figure 1. Larval abundance by station.

Optional changes to survey station allocation is discussed within this ToR as the following sections 4.2 and 4.3 relate only ToRs for the late summer survey:

Visual inspection of the data presented suggests there is strong spatial autocorrelation in abundance. There appears to be slightly longer ranges in the along-shelf direction compared with the across shelf direction. If this were numerically confirmed, then a reduction in sampling spacing along the shelf would be possible with only a minor loss in overall precision. The time released by reducing the number of vessel tracks could be used either to extend the area, and/or to add an adaptive element to the remaining transects. This would require real time evaluation of samples to determine if numbers of larvae had decreased sufficiently to define the edge of the distribution. Currently, the high values on the edges of the sampling grid (Figure 1) give some concern for overall population estimation, and give considerable uncertainty for estimation of spatial distributions through GAMs or geostatistics due to the lack of a clear boundary to the distribution. While fixed grids that stop within a distribution may estimate an index of the surveyed area without bias. If there is a probability that the distribution extends beyond the grid an index of the total population will be estimated with bias. Thus, if the spatial distribution changes among years a geo-located index will not give helpful results. It is likely the possible bias at population level introduced by an adaptive approach would be smaller than the fixed area approach (see also variance estimates below). One method is have a core grid that is always completed which can always be used for comparison. Then adaptively extend the ends of transects, adding stations, until the density of the target variables drop below a threshold. Selection of a suitable threshold should be possible from evaluation of historic data. If it is possible to define water conditions that describe suitable physical habitat for the species of interest, then this would be an even better approach. See for example Zwolinski *et al.* (2011) who have used habitat for sardine to define a survey grid, and Swartzman *et al.* (2008) who used a different method for two species, sardine and anchovy.

If the new core grid includes the area previously surveyed, but not necessarily the same grid density of stations, comparison with historic data should be possible, though the variance may be different.

A regular sampling grid is probably the most effective method for data collection. An ICES workshop in 2005 (ICES 2005) compared regular and random strategies for data collection from punctual (station) sampling and line transect sampling. In all line transect sampling regular grids out performed random transect placement. For point samples if spatial autocorrelation was low then random sampling outperformed regular sampling grids, because it was possible to collect more random placed samples in a fixed time. However, with higher spatial autocorrelation regular grids gave the best results. Conceptually, a regular grid places all stations as far away from one another as possible; thus, in the presence of correlation data it collects the most information. Walleye pollock in SEBS appears to have quite high levels of autocorrelation; thus, the regular grid is appropriate. Also, because the data is intended for modelling purposes a regular grid is likely more informative, ensuring that space is sampled evenly with no major gaps that often occur with random placement.

If a regular sample grid is used then variance estimation requires a more complex estimate of variance than a simple CV on the observations. Where the area investigated has a complex (irregular) boundary, methods are available for including this in the variance calculations in addition to the variance based on the observations. By using a regular survey grid that is extended more or less to the limits of the aggregations transitive geostatistical method provide a simple approach to variance estimation (see for example Petigas, 2001 or Rivourard *et al.* 2000), this approach is based on the assumption that the density (of O group walleye pollock, or other species) falls to zero outside the grid. This assumption will be reasonable if an adaptive method is used.

Late summer surface trawl / acoustic survey (BASIS survey)

The current survey is a station-based survey with physical, plankton and young fish data collected by several sampling methods on a regular spaced grid. The survey is considered in two regions, SE Bering Sea (SEBS) and NE Bering Sea (NEBS). The SEB survey is considered in the most detail.

Visual inspection of the walleye pollock data does not suggest any strong anisotropy in the distribution supporting the continued use of equal grid spacing in both directions. This could be checked numerically and confirmed.

The SE Bering Sea has recently had reduced area coverage of near shore sampling as the NOAA vessel has not been able to carry out surface trawls in the area.

From the data presented, it appears that the original (earlier) sampling grid and collection methodology for physical data and plankton is adequate for the purposes required. The more recent grid in SEBS may not be adequate for all purposes. In addition, there are concerns regarding the trawl sampling for young cod, walleye pollock and salmon. The indications are that the surface trawls do not adequately sample the O group walleye pollock (Figure 2). While surveys in warmer years (2003-2005) appear to catch fish and may give a good index of abundance, the O group catches in colder years (particularly 2009-2012) caught smaller quantities in the surface trawls suggesting that some of the walleye pollock may be missed by the surface trawls. Other data on these years (Ianelli *et al.* 2014) indicated average or above average yearclass strength is found on other surveys for these years. Observations based on acoustics also support that the surface trawls may miss O group fish as traces thought to be O group walleye pollock are seen at depths of 100m (De Robertis *et al.* 2014).

Taken together all this strongly supports the need for a change in biological sampling strategy for O group walleye pollock in particular this is discussed in more detail below.

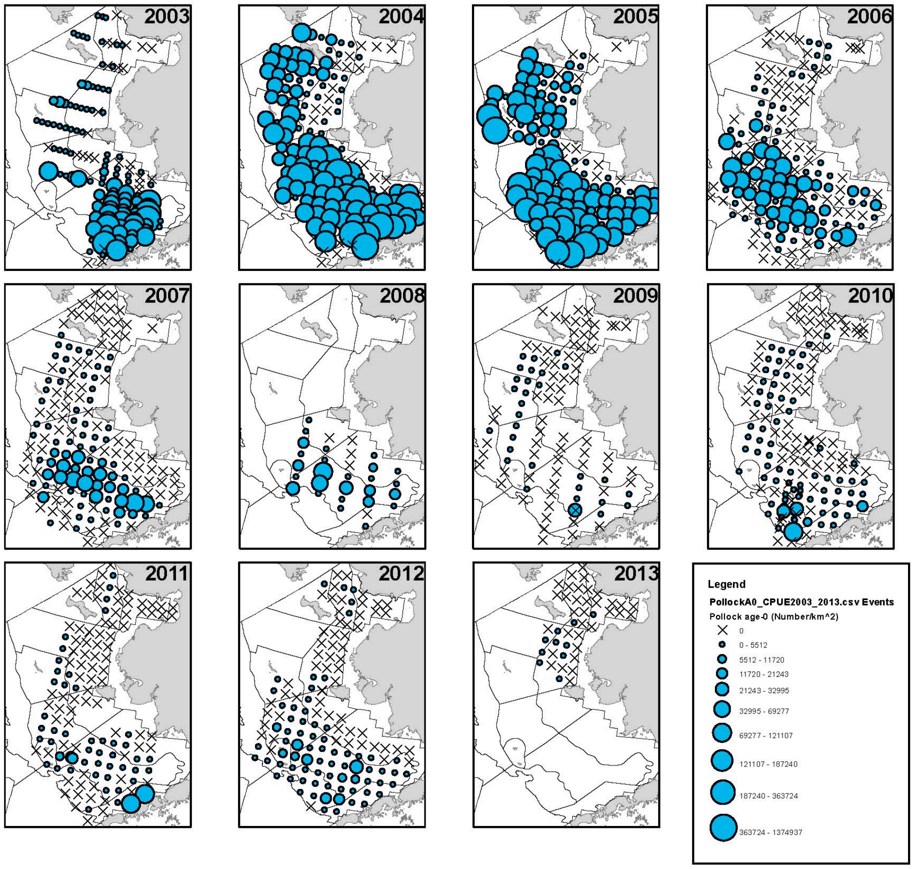

Figure 2. Bubble plots of CPUE of O group walleye pollock by station from 2003 to 2013.

Sampling for salmon has different objectives, from the sampling for O group walleye pollock, cod and arrowtooth flounder and the distribution of salmon appears to lie much closer to the coast and appears to be sampled by the surface sample gear (Figure 3).

A discussion of potential changes to the sampling design for this survey is given in Section 4.2, and the issues surrounding salmon sampling are discussed in Section 4.4.

Warm Years 2002 2007	Cool Years 2009-2011

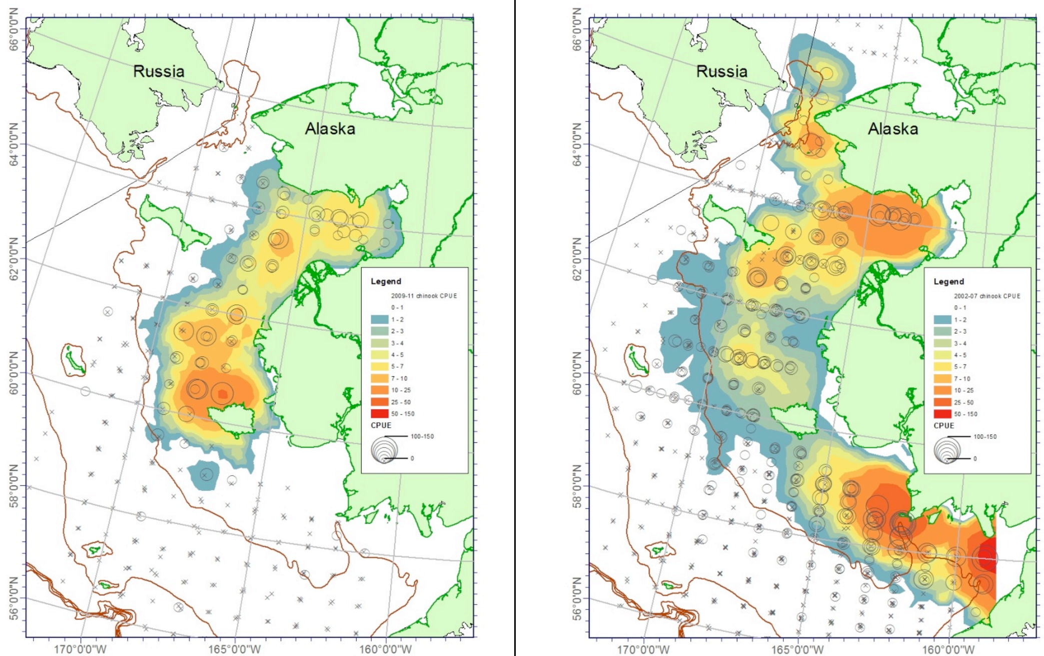

Figure 3. Comparison of the distribution of young Chinook salmon 2003-2007 and 2009-2013. (Murphy *et al.* 2013).

Conclusions: the use of regular sampling grids is considered a good approach. Extending the area coverage of the spring larval survey through adaptive sampling would be beneficial and ensure that the indices relate to population level. This might be achieved by reducing the station density by omitting alternate E-W transects. The sampling grid on the late summer YoY survey is adequate for walleye pollock, but will miss inshore Chinook salmon in the SEBS.

4.2. *Evaluation of planned change in trawl survey design, and tradeoffs of transitioning surface trawl survey with midwater acoustics to an oblique trawl survey*

Tor 3: Evaluate the planned change in trawl survey design for the late summer survey design (surface trawl with midwater acoustics to oblique trawl with acoustics), methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

ToR 4: Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of transitioning the late summer survey from surface trawl with midwater acoustics to an oblique trawl survey, particularly regarding its potential to provide comparisons between historical and future nutritional and behavioral ecology of target species.

These ToR have been combined as the discussion of the planned changes combines with a discussion of costs and benefits.

The proposed changes to the fall survey:

The changes proposed involve changes to sampling grid and to the data collected by trawl and acoustics.

Sampling grid

Based on the information provide to the review the proposed regular sampling grid appears to be adequate for spatial coverage of O group walleye pollock and cod, though there does appear to be some doubt if the grid extends far enough out to the shelf edge for arrowtooth flounder. There are considerable concerns that the inshore region between the proposed grid and the coast in the South Eastern part of the SEBS area may be important for Chinook salmon (See Section 4.4) and will not be covered with the current proposals. Previous surveys with more inshore stations appear to capture the distribution of Chinook salmon in this area (Figure 3).

Biological Sampling

As discussed above, the current surface tows do not appear to be adequate for sampling O group walleye pollock. The data shows that historic sampling of walleye pollock by surface trawl appears to be dependent on temperature with cold years giving reduced sampling efficiency. Thus, any continuity with the past based on biological sampling with the surface trawls will not really be practical and useful, as the past results appear to be strongly year dependent. This problem has been identified by the RPA.

During the surveys acoustic data has been collected and analyses in detail (De Robertis *et al.* 2014). This report provides a sensitivity analysis that indicates that an abundance index of age-0 walleye is relatively robust to the assumptions made in the analysis (e.g., target strengths used, association of trawl catches and acoustic backscatter, net selectivity) and suggests that an AT estimate of age-0 walleye pollock on the EBS shelf is possible in the context of this survey. A series of short-term and long-term recommendations for implementation of an AT-based age-0 walleye pollock abundance index are provided in the report.

The RPA is currently suggesting moving to replacing the surface tows with an oblique haul based on a $100m^2$ trawl on stations. Such an approach would be expected to provide enhance sampling as this will cover much more of the water column. However, it may be possible to obtain more information either by enhancing this approach or by moving fully to an AT approach along the lines in the De Robertis report.

The use of the station located oblique tows alone is likely to have higher variance and will give no information on vertical distribution. Vertical distribution by size is considered to be one of the potential causes of mortality as small O group walleye pollock with lower lipid diets are considered to need to feed more and to be located differently in the water column and be more prone to predation. This information on vertical distribution may be important for resolving recruitment processes. If the oblique trawl could be arranged to include opening and closing cod ends or provision of camera based target sizing (which is being developed by MACE), this would help resolve the vertical distribution issue if it was necessary to rely on trawl sampling alone. So a modified oblique with some ability to obtain vertically separated samples is a potential solution.

The inclusion of acoustics would seem to be a relatively cost effective way to obtain much more information on spatial distribution of O group fish. The acoustic equipment is already available on the OSCAR DYSON, and NMFS/UW have a group with world-class expertise which could be used to good effect if available. The costs in terms of gear and staff are not that different among the options, though there may be greater technical staff requirement for the full AT survey. The final choices depend on the prioritization of objectives.

In order to evaluate the options fully, the potential precision of the trawl/acoustic method can be compared to the oblique tows at regularly spaced station locations by sub sampling the acoustic records from those years where acoustics has been already analyzed. The variability of the acoustic data can be compared with the variability of subsets equivalent to the swept area of the oblique tows. This would inform the users of the precision advantages of continuous spatial sampling over the oblique tows. If it is concluded that there gains in precision are worth the effort, then consideration should then be given to moving to a full AT approach with trawls directed at aggregations. It is not necessary to make this transition in one go, though the sooner the final approach is agreed the better. For example if selectivity work on a chosen sampling gear is required, it need not be done in advance, though the earlier it is done the better. Overall, the inclusion of acoustic data collection is considered to be a very cost effective way to obtain data on fine scale patchiness. The RPA has already identified that the impact of feeding is important and this is occurring at much finer spatial scale than any of the spatial modeling scales. Thus, collection and understanding the patchiness of the distributions should be informative for modeling. Acoustic data on patchiness may be of considerable help, providing insights in the detail of spatial overlap among species in the long term. Some of the issues included in the recommendations of De Robertis, such as availability of staff, would be critical to success, but others such as time allocation do not seem to be an issue as long as the time currently spent on surface trawling can be diverted to the AT trawling. The De

Robertis report recommends some smaller, faster to deploy, sampling gears that will save time.

Conclusion: It seems likely that replacing the current surface trawls in necessary. An oblique tow with no vertical stratification in sampling will be an improvement but this coupled with acoustics would be a greater improvement. Allowing for vertical stratification in target identification through multiple opening and closing nets or cod end camera identification would give much needed confidence in vertical distribution of both predators and prey. Moving to a full AT survey combined with the plankton/hydrographic stations would seem to be the most effective option for walleye pollock, cod and arrowtooth flounder. If an index of for Chinook salmon were needed, an inshore SEBS coupled with NEBS survey would be an option.

4.3. *Evaluation of potential of late summer ecosystem and fishery survey to be applied to coupled biophysical-individual based models currently in use.*

ToR 5: Evaluate the potential of the spring and late summer ecosystem and fishery survey designs and analyses, or an alternative, to (i) be applied to coupled biophysical-individual based modeling and trophic modeling approaches currently in use, ii) resolving mechanistic linkages among ecosystem components, and (iii) be applied to management and conservation of walleye pollock, Pacific cod, and arrowtooth flounder within an Ecosystem Based Fishery Management approach.

The model framework presented at the review was based on a biomass structured model overlaid on a physical model with detailed horizontal and vertical grids with a short time step. The biological elements were introduced initially at age 1 for the fish species, though transport through year 0 is included in the distribution then applied. The extent of feedback from the biological model to the physical model is very limited and it may be possible to run the physical model separately to provide information of the physical environment and transport which can then be used, translated to coarser scale for biological modelling without loss of overall transport components. Currently, this modelling environment does not provide individual based modelling (IBM) and does not include explicit spatial modeling during the first year of life for the fish species. Fish are introduced at approximately age 1 but with mortality and dispersal from spawning sites included. The transport aspect of this model has been used to infer differences in larval transport related to recruitment success (Vestfal *et al.* 2013). It would seem possible to develop this model to include the early life stages on a biomass basis, rather than going to a full IBM approach. Such an approach might give some more useful insights in addition to those reported by Vestfals *et al.* (2013) with less modelling development than would be implied by development of a full IBM.

Some preliminary IBM models have been applied in the region. An individual-based model of walleye pollock early life stages was developed by coupling a hydrodynamic model to a particle-tracking model with biology and behavior (Petrik *et al.* 2014 and

Sidon *et al.* 2013). Simulation experiments were performed with the model to investigate the effects of wind on transport, ice presence on time of spawning, and water temperature on location of spawning. Changes to spawning areas, particularly spatial contractions of spawning areas in cold years, resulted in modeled distributions that were most similar to observations. The location of spawning walleye pollock in reference to cross-shelf circulation patterns is important in determining the distribution of eggs and larvae, warranting further study on the relationship between spawning adults and the physical environment. This study emphasizes the influence of determining spawning location and early egg and larval transport. Also identified was the potential for spatial mismatch between YoY and their prey potentially causing poor survival.

These modeling studies reinforce the need for the spring larval survey to determine the location of spawning grounds. Data on early availability of food conditions along with the information on the physical environment also come from this survey. In this context colocation sampling is particularly useful in such situations, so the uncertainty and variability across locations can be observed and compared with models. The late summer YoY survey is needed to investigate growth and survival to that time before winter, to establish if mortality is occurring before or during winter.

Conclusions: the co-located sampling of physical, planktonic and larval fish stages in the spring is of considerable importance for current and potential modelling development. Where possible, the survey grid should be designed to capture the full population ranges of the species of interest, ensuring that model comparison and inference can be related to population level. The YoY surveys in the late summer should also continue with co-located sampling to determine the population level status of YoY and the size, condition and location as the yearclass enters the winter.

4.4. Evaluation of the potential of the ecosystem and fishery survey for a western Alaska Chinook salmon 'abundance based cap'.

ToR 6: Evaluate the potential of the late summer ecosystem and fishery survey design and analysis, or an alternative, to incorporate these data in a western Alaska Chinook salmon the estimation of an 'abundance based cap' for prohibited species catch within the Bering Sea walleye pollock fishery in comparison to the proposed 'abundance based cap' using estimates of adult western Alaska Chinook salmon returns as proposed within the North Pacific Fishery Management Council.

The Review Panel received two major presentations relating to bycatch of Chinook salmon, looking at the current bycatch management cap on bycatch of Chinook salmon in the walleye pollock fishery. This is currently based on a fixed cap that is reduced following a low return year. It is unclear if the primary purpose of the bycatch limit is to limit mortality rate per year due to bycatch or to limit overall bycatch irrespective of mortality rate. It would appear reasonable to allow larger potential runs to incur higher numerical bycatch while reducing bycatch in low years, aiming at something like a maximum bycatch impact rate, rather than a fixed value in all years which would imply higher mortality in poor years.

While the current Chinook bycatch cap strategy is not directly related to the abundance of Chinook salmon expected in the area, it does respond to low abundance by reducing the cap for the following year. Examination of the data suggests there is a correlation in numbers per year returning between years (comparing the horizontal distribution of points by year in Figure 4). This suggests that there would be a relationship between an estimate in one year and the next; however, the lowest run return years follow years that can still be substantially higher, and conversely the low years are followed by years with runs that can be about twice the magnitude, e.g. 2000 followed by 2001 for the Upper Yukon (Figure 4). This suggests the reduced bycatch limit approach is not optimal and could lead to higher bycatch mortality in some years and greater, but not really necessary, restriction in others.

The historic impact rate is below 8% for the whole area and below 4% for the Upper Yukon (Figure. 5). The impact rate in the Upper Yukon is correlated with the general impact over the area as a whole even though the proportion of the total area that returns to the Upper Yukon has only been between about 10-20% of the total.

A regression between the late summer YoY survey estimate of Chinook salmon from surface trawls in NEBS shows that an index based on this data is able to provide an estimate of YoY Chinook salmon which might be suitable to be used to set bycatch caps for the following year. Such an approach would provide better coherence between abundance of young salmon likely to be potential bycatch and the limit. This could be used to allow higher limits in good return years and imposing achievable greater restraint in poor years.

Assuming the survey utilizing surface trawl to target Chinook salmon will continue during even years in the NEBS, this survey could be extended to cover the coastal waters of SEBS in these even years. Up to now there has not been any effort to include the Chinook data from the SEBS region in the model due to lack of time series data. However, it would be expected that more information would give a better regression overall.

The Canadian origin Chinook salmon regression relationship (Figure 6) shows promise as a leading indicator for abundance of these Chinook salmon in the bycatch. It could be checked against Chinook for the whole region covered by the survey using existing data. As runs in other rivers in the region appear to be correlated with Canadian returns in recent years, it seems possible that the current Canadian Origin model, may be useful for establishing marine mortality estimates that may be applied to the western Alaska Chinook populations as a whole, and thus to set overall bycatch targets.

If this provides useful management information, investigation of an annual surface trawl surveys in the NEBS and extended to nearshore in the SEBS should be carried out.

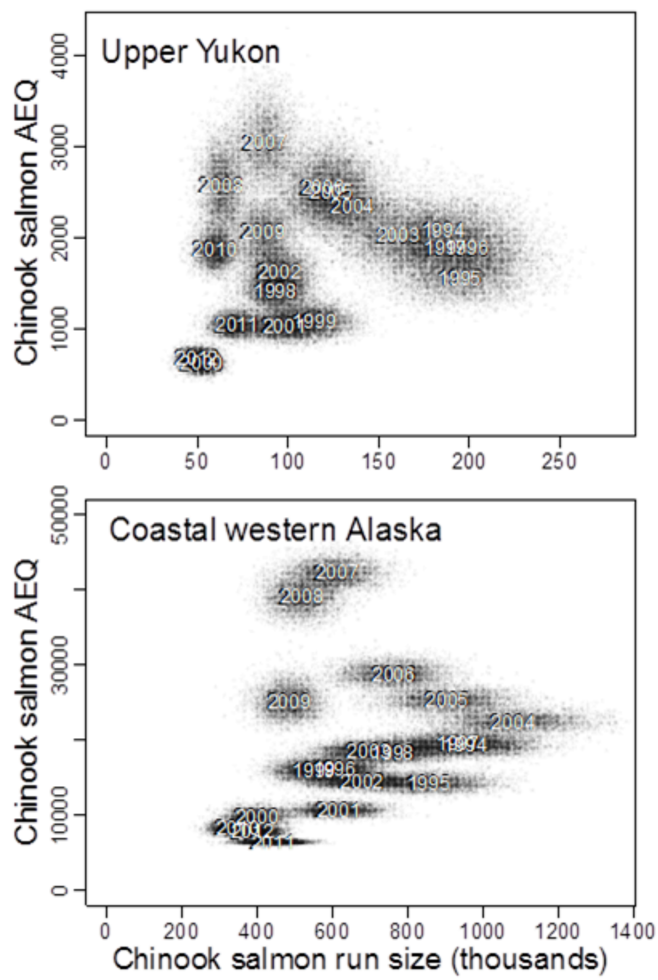

Figure 4. Relationship between numbers of Chinook salmon run size and bycatch.

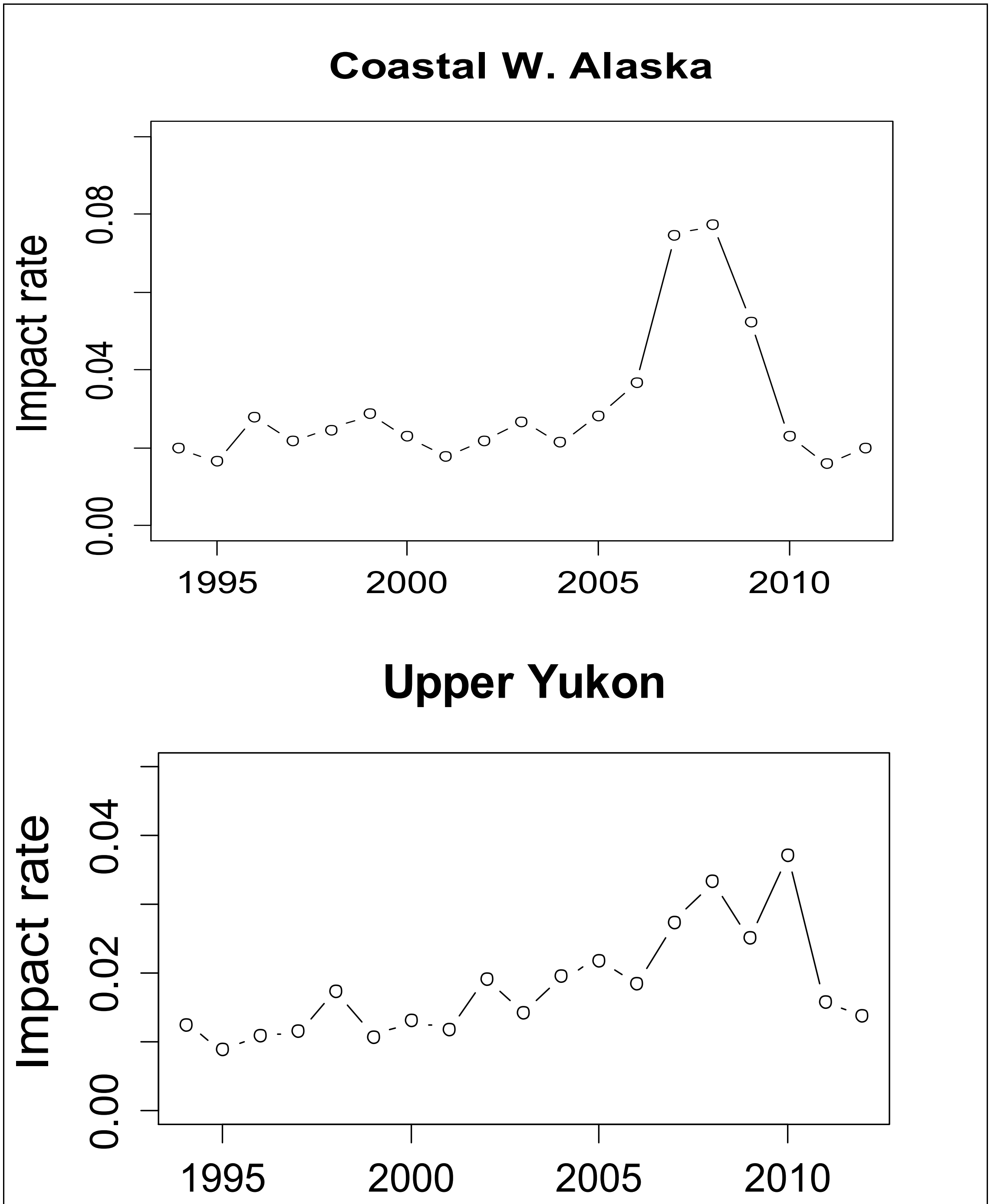

Figure 5. Estimated fraction of returning run taken as bycatch.

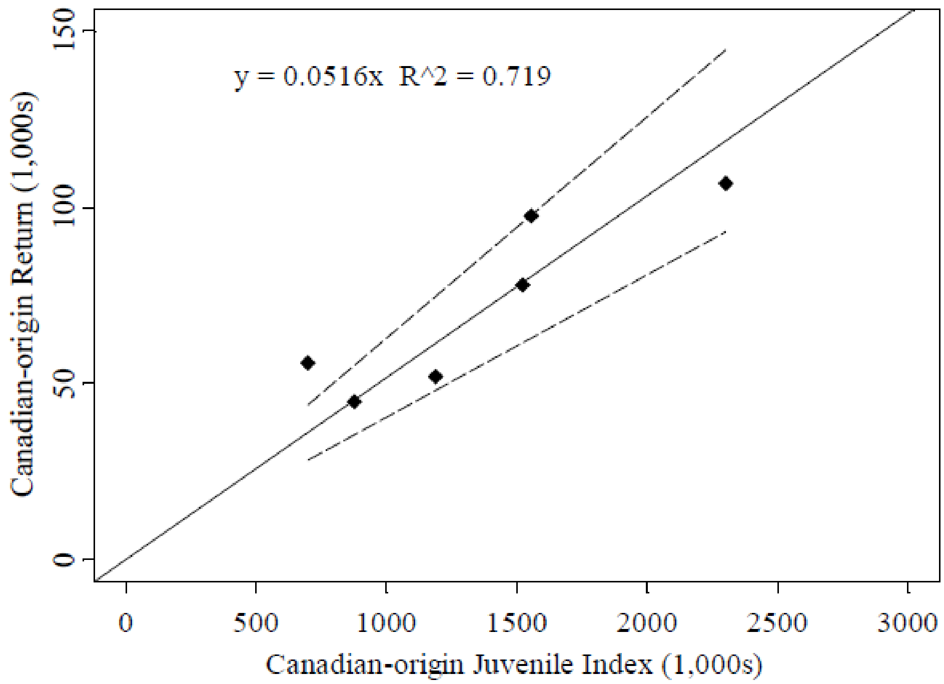

Figure 6. Regression (with zero intercept) between survey index of Canadian origin juveniles and returning adults.

Conclusions: Further work should be done to test the current relationships between total Chinook salmon bycatch and Upper Yukon returns to determine if the precision of this regression provides a basis for bycatch advice for the whole area. If the use of this leading indicator improves the prediction of impact rate over the current methodology, then further evaluation of precision is needed to ensure bycatch limits are neither unnecessarily restrictive nor lax. If more precision is needed, then the extent of the NEBS salmon survey should be increased to include the SEBS coast area, covering more completely Chinook salmon on the EBS.

4.5. Evaluation of tradeoffs of separate/joint surveys every year or every other year.

ToR 7: Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of:

a. *separate Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling*
b. *joint Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling, particularly regarding their potentials to: i) evaluate the nutritional and behavioral ecology of Chinook salmon, walleye pollock, Pacific cod, arrowtooth flounder, and ancillary forage species; ii) put that information into the context of*

their biotic and abiotic environments; and iii) characterize their roles in the eastern Bering Sea Ecosystem. Provide specific recommendations for short- and long-term improvements to anticipated compromises associated with spring and late summer ecosystem surveys.

In addressing this issue, the ToR suggests a cost-benefit analysis. No analysis was presented at the review. Specific costs in $ or days were not described and the benefits were more general. In trying to provide some input to the ToR, I have identified a number of 'products' which have been mentioned during the review. I have used these to discuss cost/benefit of the different options. I am unable to assign relative weight to these different products so the tradeoffs are expressed in more general terms. There may also be other important 'products' that I have missed.

Survey separation

Separation of walleye pollock and salmon surveys has some advantages. The salmon surveys need to cover similar areas in NEBS, but need to be concentrated more inshore in the SEBS. The salmon appears to be sampled best with surface trawls, whereas the walleye pollock is not caught in the surface trawls in all years. It is unclear if the oblique tows or indeed acoustics would sample salmon adequately. The proposed AT gear would be difficult to deploy close to the surface and the oblique towed gear may stop or fish poorly in the upper 10-15m of the water column as the gear returns to near the vessel the spread may reduce as the vessel slows bring in the gear to the rear of the vessel. A combined salmon/walleye pollock survey could deploy different gears in different parts of the area, but the OSCAR DYSON is not able to deploy the surface trawl for salmon in the shallower water in the SEBS, making this option particularly poor. The inclusion of plankton and hydrographic sampling on the salmon survey would be useful for model development for the Bering Sea, but is probably a lower priority.

The walleye pollock survey should include sampling for plankton and hydrography to link with development of O group because of the need to link this to its environment.

I would conclude that if funding for a separate salmon survey were available this would be a good option.

Annual/Biennial surveys

The costs of an annual / biennial survey are likely to be slightly greater for staff time and double for ship costs. Staff time spent preparing and carrying out data collection in the second year would be used for analytical work if there was no survey. Thus, while a survey every year would collect information at twice the pace, more time would be available to spend considering the information with the biennial program.

The request is to consider the evaluation of nutritional and behavioral ecology of Chinook salmon, walleye pollock, Pacific cod, arrowtooth flounder, and ancillary forage species, and the use of this information to set these populations in the context of their biotic and abiotic environments and characterizing their roles in the eastern Bering Sea Ecosystem. For this purpose biennial/annual salmon surveys are considered separately from the other species. For the other species, a set of specific outputs using the data are identified and the effect of biennial/annual collection is discussed in terms of these 'products'.

Salmon surveys

Biennial salmon surveys would make it more difficult to give annual advice on bycatch limits based on abundance estimation. While salmon remain in the sea for a number of years, skipping survey years implies having a good knowledge of at sea mortality which is not yet at the stage where it can be predicted. Development of multiple age based indices from biennial surveys would be required, and this has not yet been tested. Nevertheless, biennial surveys will give some information on bycatch for two years, and as such, biennial surveys are an improvement on no salmon survey at all. If the bycatch issue is of major concern, and this was the impression given at the review panel meeting, then an annual survey would be the best approach, reducing this to biennial if it proves possible to derive two indices from one survey with sufficiently accuracy.

For the walleye pollock, cod and arrowtooth flounder collecting all the ecosystem data on all surveys will greatly increase the likelihood of understanding the links between the juvenile fish and their biotic and abiotic environment. The costs of getting ship and personnel to the sampling locations and collecting only part of the data would appear to be a poor option, so maintain full data collection would seem to be a cost effective option.

The three major products from the SEBS and NEBS walleye pollock surveys are: a) the ecosystem stories that are used in the IEAs and in developing understanding of the effects of fishing on the ecosystem; b) model based mechanistic approaches to estimation of recruitment for use in fisheries management without the need for observation; and c) the addition of an observation based index of recruitment for walleye pollock (and cod and arrowtooth flounder).

The first of these, the ecosystem stories, can probably be supplied from a biennial survey without major degradation. Update of indicators biennially is probably sufficient and although understanding will develop more slowly, the impact will probably be minor.

The second, the mechanistic model, will develop more slowly with biennial surveys as the number of data rich annual events to develop and test a model will be half that in the biennial regime; however, the pace of model development could be similar. A recruitment model is currently not yet up and running and needs to be added to the current spatial model. Thus, there is a need for model development. However, it is likely that at least 5 years more data will be needed and model development should be possible on such a timescale, so it seems unlikely that data collection will outstrip model development.

The third product, the observational/model index, will develop more slowly, probably in line with the number of data years. Testing the suitability of an index for inclusion in the assessment will require say 5 years of information to compare with 5 years in the assessment. Currently, the SEBS surveys are not delivering good indices of abundance of O group walleye pollock because of the trawl sampling issues. Thus, it will be more than 5 years with annual surveys and more than 10 years with biennial surveys before such an index is likely to be available, and tested, for use in an assessment. At the very least, biennial surveys compared with annual surveys will increase the time period by about 5 years.

Although the current assessment provides precise estimates of abundance in the assessment year, forward projection does cause some additional error. This is particularly important when the incoming yearclass is projected forward to age four. Recently one large yearclass contributed over 50% of the estimated catch for one year. For small year classes the increased uncertainty is a minor issue, as then the older more certain yearclasses will contribute more to the fishery. If the industry requires more precise estimates of recruitment, then improved recruitment models would appear to be the best option. Given that exploitation is at Fs below Fmsy and increased uncertainty will tend on average to reduce F further, long-term yield might be expected to be further below MSY when uncertainty is greater, therefore there is some commercial advantage in improved precision of recruitment, particularly for large year classes.

Conclusion: It is preferable to separate the salmon survey from the surveys of recruitment because the needs and outputs are very different. For walleye pollock, Pacific cod and arrowtooth flounder, biennial surveys are probably adequate for general ecosystem stories and provision of indicators for IEA. Annual surveys would greatly speed up the process of both mechanistic/IBM model based recruitment indicators. Also annual surveys would be much better placed to give O group or improved 1 group indexes of walleye pollock for use in the assessment.

4.6. Evaluation of gaps and inconsistencies in process research

ToR 8: Evaluate gaps and inconsistencies in process research, particularly regarding the potential of research practices to provide mechanistic information to Integrated Ecosystem Assessments and Ecosystem Based Fishery Management practices.

The current approach provides considerable utility for the formulation of ecosystem stories, to explain the sensitivity and dependence of recruitment on the varying environment. The surveys also supply a range of ecosystem indicators either annually or biennially, which can inform the biological aspects of IEAs for the region. Perhaps the most important output from the work so far is the strong link between climate and recruitment linked through the ice coverage. The availability of a biological model with good climate coupling able to give ice coverage translated to recruitment is a very powerful output. The stochastic aspects may not be captured fully, so the model forward predictions may be smoother than will really happen, but the general trajectory appears well founded.

The major element of uncertainty in the current study is to identify the relative importance of different times of year to age 0 mortality. While the greatest mortality rates with the greatest potential for annual differentiation occur in the first 6 months of life, an important source of mortality based on condition (size and lipid content) has been identified as a potential source of mortality during the second semester. The ability to correctly identify where the most important mortality differences occur would greatly improve the ability to carry out model validation. Currently this does not seem to be easy.

The current O group surveys based predominantly on surface trawl data have proved difficult to compare across warmer and colder years, so that a comparable population index for the autumn has not been reliably obtained. Evaluations of energetics (Heinz *et al.* 2013 and Gann *et al.* 2015) strongly suggest that the smallest YoY will have a low probability to survive the winter, and comparison between weight at age at age 1 and length distribution at age 0 suggests that small fish either catch up or die between the autumn and the time of the acoustic/ground fish surveys the following year. There are two ways of determining if this is the main cause of mortality. For example, comparing the abundance of 0 group in the autumn with 1 group the following year may be able to partition the mortality into first and second semester mortality. However, the overall process variability of recruitment is thought to be a CV of approximately 0.8, (Ianelli *et al.* 2014) a combination of acoustic and groundfish surveys gives a measurement precision with CV of approximately 0.6, which is not a large increase in precision over the process error. So the ability to reliably assign mortality to one or other of the first semesters based on an O group survey to compare with the 1 group assessment surveys is not promising. Finding a way to evaluate the size and energy status of the YoY through the winter may be a better way to answer the question. The commercial fishery does not sample 0 group fish, but if it was possible to use fishing boats to deploy simple samplers to obtain samples of O group fish for size and condition evaluation this might yield results on the experience (growth or mortality) of the smaller individuals through the winter.

Conclusion: The major gap in the information currently being collected is data to explicitly confirm the extent to which the winter mortality is the primary mechanism for determining yearclass strength for walleye pollock. Survey solutions to this issue appear to be limited, there may be some benefit in attempting to obtain samples of O group walleye pollock through the winter.

5. Panel review proceedings

I was impressed overall with the quality of the work presented at this review. The program has become coordinated and is bringing together all the tools to build an understanding of recruitment processes; this after all is the holy grail of fisheries science. The RPA program is more complete and better focused than any other program in recruitment processes that I am aware of. I would like to thank all involved for their efforts to bring together all the various studies. During the review everybody was very constructive and helpful, in particular the effort to provide daily minutes was particularly appreciated.

Regarding process, there are ways this could have been improved. Rereading the original request for participation and final ToR, it is possible to see the links and understand what was being requested, but it was not easy to determine the final ToR from the original request. If this is repeated, it might have been better to start the process with the ToR. ToR 6 on salmon bycatch was not referred to at all in the original request. During the review it was difficult to draw out clearly what changes were being proposed so they could be evaluated in this report. It might have been easier for the reviewers to obtain clear responses to each of the ToR if the review were timetabled specifically by the ToR. While it was appreciated that there was a need for a great deal of background, which was very well provide over the first day and a half, focus on some ToRs was poor, this is best illustrated by Wednesday afternoon, where all presentations were related to more than one and up to four of the eight ToRs in the one session. For those who were familiar with the work this was not an issue, but for an external reviewer it was less obvious.

6. Conclusion

The quality of the work presented at this review is more complete and better focused than any other program in recruitment processes I have seen. The RPA should be commended for their efforts.

While the background material was extensive and very well supported with publications, it was difficult to review detail in the data analysis methods. The peer reviewed publications provide verification of good practice but details of analytical approaches were not provided. Conceptual information on the modelling was available but the detail of the modelling was not available, though not strictly necessary for the review.

The co-located sampling of physical, planktonic and larval fish stages in the spring is of considerable importance for current and potential modelling development. Where possible, the spring survey grid should be designed to capture the full population ranges of the species of interest, ensuring that model comparison and inference can be related to population level. The YoY surveys in the late summer should also continue with co-located sampling to determine the population level status of YoY and the size distribution, condition and location of these fish as the yearclass enters the winter.

Because the needs sampling and area coverage are different, it is concluded that it is preferable to separate the salmon survey from the surveys of recruitment for walleye pollock, Pacific cod and arrowtooth flounder.

Biennial surveys are probably adequate for general ecosystem stories and provision of indicators for IEA. Annual surveys would greatly speed up the process of both mechanistic/IBM model based recruitment indicators. Also, annual surveys would be much better placed to give O group or improved 1 group indexes of walleye pollock for use in the assessment.

The major gap in the information currently being collected is data to explicitly confirm the extent to which it is the summer or winter mortality that is the primary mechanism for determining yearclass strength for walleye pollock. Improved late summer YoY surveys will help with this issue. However, survey solutions to estimation mortality through the winter appear to be limited, but there may be some benefit in attempting to obtain samples of O group walleye pollock through the winter for comparison of size and energetics through the season until the 1 group surveys the following year.

For salmon bycatch there is a need to test a relationships between Upper Yukon returns and total Chinook salmon bycatch to estimate if the precision of this regression provides a basis for overall area advice. If use of this index improves the prediction of impact rate over the current methodology, then it would be useful to further evaluate if more precision is needed to ensure bycatch limits are neither unnecessarily restrictive nor lax. If more precision were needed, then an extension of the NEBS salmon survey to the SEBS coast area would be the next step.

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Appendix 2 : Statement of Work

External Independent Peer Review by the Center for Independent Experts

Review of Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem

Scope of Work and CIE Process: The National Marine Fisheries Service (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: We request an independent CIE review of the ecosystem and fisheries recruitment processes applied research conducted at the NMFS's Alaska Fisheries Science Center (AFSC). Ecosystem and fisheries research has been conducted by various programs within the AFSC for over 30 years. Recently several of these programs came together to form the Recruitment Processes Alliance (RPA), which joins expertise, merges effort, and facilitates scientific exchange in the study of Arctic and North Pacific ecosystem functioning. The RPA, comprised of the Recruitment Processes program (the Ecosystems and Fisheries Oceanography Coordinated Investigations or EcoFOCI), the Ecosystem Monitoring and Assessment (EMA) program (the Bering Arctic-Subarctic Integrated Survey or BASIS), the Marine Acoustics and Conservation Engineering (MACE) program, the Resource Ecology and Ecosystems Modeling (REEM) program, and the Resource Energetics and Costal Assessment (RECA) program, as well as the members of the EcoFOCI Program that reside at the Pacific Marine Environmental Laboratory (PMEL). This effort is a unique collaboration among NMFS programs within the AFSC and across-line offices (National Marine Fisheries Service and Oceanic and Atmospheric) with a primary goal to provide mechanistic understanding of the factors that influence recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing the first year of ocean life. To accomplish this, seasonal (spring, summer, autumn) field surveys and process-oriented research are conducted to inform single-species, multi-species, and biophysical ecosystem models. Survey methods rely on gridded net tows and selected use of acoustics to collect target species, with concurrent oceanographic and environmental sampling to estimate biological and physical oceanographic structuring forces. For this review, an impartial evaluation of the joint, RPA fisheries-oceanographic research of the Eastern Bering Sea will be conducted to evaluate the survey methodology and analytical approaches used to estimate relative abundance, distribution, biomass, and physiological condition of target species, the biophysical environmental variables thought to structure recruitment of target species, and the incorporation of observed variables into ecosystem forecast models, Integrated Ecosystem Assessments (IEAs), and Ecosystem Based Fishery Management (EBFM) practices. The terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

Requirements for CIE Review:
Four CIE experts shall participate in a panel peer review in accordance with the SoW and ToRs herein. The review panel shall have the combined expertise and working knowledge in (1) recruitment processes surveys and design including fisheries-oceanographic plankton and trawl survey design, operation, sampling and analysis; (2) familiarity with ocean ecology of early life stages of groundfish and salmonid species, (3) field methods, including acoustics for process studies, and spatial sampling and analysis of distribution and abundance of young fish; (4) experience in Ecosystem Based Fishery management and/or Integrated Ecosystem Assessment; (5) climate-coupled single-species, multi-species, and biophysical models. Each CIE reviewer is requested to provide a separate and independent evaluation. The CIE reviewer's duties shall include (1) conducting pre-review preparations with document review; (2) participation in panel review meeting; and (3) completion of a CIE independent peer review report in accordance with the ToR and the Schedule of Milestones and Deliverables. The agenda for the Panel review meeting will be provided to reviewers along with background materials two weeks prior to the panel meeting. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Location/Date of Peer Review: Four CIE experts shall participate during a panel review meeting scheduled at the **AFSC in Seattle, Washington** to be held during the dates of **July 21-24, 2015.**

Statement of Tasks: Each CIE expert shall complete the following tasks in accordance with the SoW, ToRs and Schedule of Milestones and Deliverables specified herein.

<u>Prior to the Peer Review</u>: Upon completion of the CIE expert selection by the CIE Steering committee, the CIE shall provide the CIE expert information (name, affiliation, and contact details) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to each CIE expert. The NMFS Project Contact is responsible for providing the CIE experts with the background documents, reports, foreign national security clearance, and information concerning other pertinent information. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE experts participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE experts who are non-US citizens. For this reason, the CIE experts shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to each CIE expert all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance with the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Panel Review: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs. Modifications to the SoW and ToR cannot be made during the peer review, and any SoW or ToR modification prior to the peer review shall be approved by the COR and CIE Lead Coordinator. Each CIE expert shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their tasks shall be focused on the ToRs as specified in the contract SoW.

The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer **shall complete** the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables.**

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;

2) Participate during the panel review meeting in **Seattle, Washington** during **21-24 July 2015**, and conduct an independent peer review in accordance with the ToRs (**Annex 2**);
3) No later than **7 August 2015**, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to mshivlani@ntvifederal.com, and to Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas@miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE **shall complete** the tasks and deliverables described in this SoW in accordance with the following schedule.

29 June 2015	CIE sends the reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
6 July 2015	NMFS Project Contact sends the CIE Reviewers the pre-review documents
21-24 July 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
7 August 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
21 August 2015	CIE submits the CIE independent peer review reports to the COTR
28 August 2015	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This "Time and Materials" task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and the Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToR within the SoW as long as the role and ability of the CIE experts to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables

(CIE independent peer review reports) to the COR (Allen Shimada, via allen.shimada@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) the CIE reports shall have the format and content in accordance with **Annex 1**, (2) the CIE reports shall address each ToR as specified in **Annex 2**, (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COR. The COR will distribute the approved CIE reports to the NMFS Project Contact and regional Center Director.

Support Personnel:

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Manoj Shivlani, CIE Lead Coordinator
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Key Personnel:

NMFS Project Contacts:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. Each CIE independent report **shall be prefaced** with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of each peer review report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe using their own words, the review activities completed during the panel review meeting, including a detailed summary of findings, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. Each CIE independent peer review report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not they read the summary report. Each CIE independent report shall be an independent peer review of each ToRs.

3. Each report shall include the appendices as follows:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership and other pertinent information from the panel review meeting.

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Annex 2: Terms of Reference for the Peer Review

Terms of Reference (ToR) for the Center for Independent Experts Panel Review of the Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem.

Each CIE reviewer **will conduct an independent peer review** addressing each ToR;

a. Review background materials and documents that detail the ecosystem and fishery survey design and methods, and data analysis methods and results for:
    a. Joint walleye pollock, Pacific cod, and arrowtooth flounder surveys;
    b. Chinook salmon and chum salmon survey
    c. Joint bio-physical oceanographic survey component (ecosystem).

b. Evaluate the *historic*, spring and late summer ecosystem and fishery survey designs, methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

c. Evaluate the *planned change* in trawl survey design for the late summer survey design (surface trawl with midwater acoustics to oblique trawl with acoustics), methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

d. Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of transitioning the late summer survey from surface trawl with midwater acoustics to an oblique trawl survey, particularly regarding its potential to provide comparisons between historical and future nutritional and behavioral ecology of target species.

e. Evaluate the potential of the spring and late summer ecosystem and fishery survey designs and analyses, or an alternative, to (i) be applied to coupled biophysical-individual based modeling and trophic modeling approaches currently in use, ii) resolving mechanistic linkages among ecosystem components, and (iii) be applied to management and conservation of walleye pollock, Pacific cod, and arrowtooth flounder within an Ecosystem Based Fishery Management approach.

f. Evaluate the potential of the late summer ecosystem and fishery survey design and analysis, or an alternative, to incorporate these data in a western Alaska Chinook salmon the estimation of an 'abundance based cap' for prohibited species catch within the Bering Sea walleye pollock fishery in comparison to the proposed 'abundance based cap' using estimates of adult western Alaska Chinook salmon returns as proposed within the North Pacific Fishery Management Council.

g. Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of:
    a. separate Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling
    b. joint Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling, particularly regarding their potentials to: i) evaluate the nutritional and behavioral ecology of Chinook salmon, walleye pollock, Pacific cod, arrowtooth flounder, and ancillary forage species; ii) put that information into the context of their biotic and abiotic environments; and iii) characterize their roles in the eastern Bering Sea Ecosystem. Provide specific recommendations for short- and long-term improvements to anticipated compromises associated with spring and late summer ecosystem surveys.

h. Evaluate gaps and inconsistencies in process research, particularly regarding the potential of research practices to provide mechanistic information to Integrated Ecosystem Assessments and Ecosystem Based Fishery Management practices.

Appendix 3 Attendance and Review Group Agenda

Workshop Participants

CIE Panel

Ken Drinkwater (CIE, IMR Bergen, Norway)
Paul Fernandes (CIE, Aberdeen University, UK)
John Simmonds (CIE, ICES, Copenhagen, Denmark)
Tony Smith (CSIRO, Hobart, Australia)

Alaska Fisheries Science Center

Kerim Aydin
Morgan Busby
Alex De Robertis
Martin Dorn
Janet Duffy-Anderson
Lisa Eisner
Ed Farley
Daniel Geldof
Anne Hollowed
Ron Heintz
Jim Ianelli
Libby Logerwell
Ann Materese
Phil Mundy
Jeff Napp
Steve Porter
Mike Sigler (Moderator)
Adam Spear
Heather Tabisola
Chris Wilson
Ellen Yasumiishi
Samantha Zeman
Stephanie Zador
Adam Spear

Pacific Marine Environmental Lab

Nick Bond
Al Herman
Carol Ladd
Calvin Mordy
Phyllis Stabeno

Attendees from outside AFSC/PMEL

Nick Bond, Southwest Fisheries Science Center
Keith Criddle, University of Alaska Fairbanks
Kelly Kearney, University of Washington
Melissa Haltuch, Northwest Fisheries Science Center
Yvonne Ortiz, University of Washington
Lauri Sadorus, International Pacific Halibut Commission
Elizabeth Siddon, NRC post doc
Heather Tabisola, University of Washington
David Witherell, North Pacific Fisheries Management Council

Workshop agenda (Draft July 16)

7.1. Tuesday, July 21 – Physics, Lower Trophic Dynamics, and Modeling

Hypothesis: Climate change and variability have predictable effects on the bottom-up and top-down mechanisms, which regulate fisheries recruitment in Alaska

Time	Event	Speaker(s)
8:30	Coffee, available at AFSC	
9:00	Welcome, Introduction, Terms of Reference, Charge to the Reviewers	M. Sigler
9:15	Overview: Ecosystem and process work in the context of the mission of NOAA Fisheries & AFSC; History: from BSIERP to the RPA; Motivation for research - overarching goals and priorities (Terms of Reference: ToR 1)	M. Sigler
9:45	SEBS Ecosystem Based Oceanography: Climate regimes, physical oceanography, sea ice dynamics & phenology, nutrients, and long-term monitoring (ToR 1)	P. Stabeno, C. Ladd
10:15	*Break*	
10:30	Lower Trophic Ecology: Mechanisms of influence of atmospheric, oceanic, nutrient effects on phytoplankton and zooplankton, current understanding, and key uncertainties (ToR 1)	L. Eisner, J. Napp
11:00	Lower Trophic Modeling: Forecasting and key variables (ToR 1)	K. Aydin
11:15	Physical Projection Modeling: Short-term and long-term (ToR 1)	A. Hermann, N. Bond
11:45	Open Discussion: Question and Answer (ToR 1)	M. Sigler, moderator
12:00	**Lunch** **Poster Session A**	
13:30	Historical and Current Oceanographic and Lower Trophic Sampling: FOCI (ToR 2)	J. Duffy-Anderson
14:00	Open Discussion: Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design (cost/benefits); Potential of research to identify mechanisms, increase understanding and inform modeling (ToR 2)	M. Sigler, moderator
15:00	*Break*	
15:15	Historical and Current Oceanographic and Lower Trophic Sampling: EMA (ToR 2)	E. Farley
15:45	Open Discussion: Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design	M. Sigler, moderator

16:45	End of Day	

7.2. Wednesday, July 22 – Groundfishes and Modeling

Hypothesis: The effects of climate and ecosystem function on fish recruitment are most evident during 2 critical periods: 1) early to late larval state when mortality is a function of growth and 2) the first winter when mortality is a function of size and energy stores

Time	**Event**	**Speaker(s)**
8:30	Coffee, available at AFSC	
9:00	Groundfishes: Ichthyoplankton Ecology (walleye pollock, Pacific cod, arrowtooth flounder). Description of spawning, eggs, larval, early juvenile ecology and key uncertainties; Mechanisms of influence of ocean physics and lower trophic on fish early life ecology (ToR 1)	J. Duffy-Anderson
9:30	Groundfishes: Juvenile Ecology (walleye pollock, Pacific cod, arrowtooth flounder). Description of juvenile ecology and key uncertainties; Mechanisms of influence of ocean physics and lower trophic on fish juvenile ecology (ToR 1)	E. Siddon
10:00	Pollock Condition and Recruitment Index (ToR 1)	R. Heintz
10:15	*Break*	
10:30	Trophic Modeling: Fish-Euphausiid Abundance in Space and Time (FEAST); Current conceptual model and parameter estimates (ToR 1)	J. Ortiz, K. Aydin
11:30	Open Discussion: Question and Answer (ToR 1)	
12:00	**Lunch** **Poster Session B**	
13:30	Ichthyoplankton Sampling: Historical spring groundfish early life stage sampling. Planned changes to support fish ecology questions and ecosystem modeling; Data, analyses, and products (ToR 5, 8)	J. Duffy-Anderson
14:00	Open Discussion of Ichthyoplankton Sampling. Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design (cost/benefits); Potential of research to identify mechanisms, increase understanding and inform modeling (ToR 5, 8)	M. Sigler, moderator
15:00	*Break*	
15:15	Juvenile Sampling: Historical summer juvenile groundfish sampling. Planned changes to support fish ecology questions and ecosystem modeling. Data, analyses, products (ToR 3, 4, 5, 8)	E. Farley
15:45	Open Discussion of Juvenile Sampling. Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design (cost/benefits); Potential of research to identify mechanisms, increase understanding and inform modeling. (ToR 3, 4, 5, 8)	M. Sigler, moderator

16:45	End of Day	

7.3. Thursday, July 23 - Ecosystem Based Fishery Management and Salmon Ecology and Modeling

Time	**Event**	**Speaker(s)**
8:30	Coffee, available at AFSC	
9:00	North Pacific Fisheries Management Council (NPFMC) and ecosystem-based scientific advice. What are the mandates to do EBFM, what are the leading issues in Alaska, and what are opportunities for providing actionable advice (ToR 1, 5, 8)	A. Hollowed
9:30	The NOAA Integrated Ecosystem Assessment (IEA) Program, the Bering Sea Ecosystem Plan, processes for how the AFSC conducts and operationalizes ecosystem science in management (ToR 1, 5, 8)	K. Aydin
10:00	*Break*	
10:15	The incorporation of ecosystem information into single-species stock assessments, multi-species stock assessments, and management strategy evaluations (MSEs) (ToR 1, 5, 8)	J. Ianelli
10:45	Ecosystem indicators and ecosystem assessments in the Alaska region (ToR 1, 5, 8)	S. Zador
11:15	RPA products developed or delivered for Alaska EFBM: Working Groups, Species Report Cards, and Indicators (ToR 1, 5, 8)	E. Yasumiishi
11:45	Open Discussion: Question and Answer	M. Sigler, moderator
12:00	**Lunch** **Poster Session C**	
13:30	Management of Salmon Resources (ToR 1)	J. Ianelli
14:00	Overview Chinook, Chum salmon: Description of early life ocean ecology and key uncertainties; Mechanisms of influence of ocean physics and lower trophic on fish early life ecology (ToR 1)	E. Farley
14:30	Trophic Modeling: Chinook FEAST. Current conceptual model and parameter estimates for Chinook FEAST (ToR 6, 8)	K. Aydin, I. Ortiz, A. Hermann, K. Kearney
15:00	*Break*	
15:15	Historical and Current Salmon Sampling: Historical sampling, planned changes to support fish ecology questions and ecosystem modeling; Data, analyses, and products (ToR 6, 8)	E. Farley
15:45	Open Discussion: Evaluate trade-offs and cost/benefit of separating salmon and groundfish surveys; Conducting biennial sampling for the southeast Bering Sea; and improvements and/or caveats (ToR 7, 8)	M. Sigler, moderator
16:45	End of Day	

7.4. Friday, July 24 – Q&A and Wrap-up

Time	Event	Speaker(s)
8:30	Coffee, available at AFSC	
9:00	Q&A with Reviewers and Presenters: Ocean Physics, Lower Trophic, and Modeling	M. Sigler, moderator
10:00	Q&A with Reviewers and Presenters: Fish Species (Groundfishes, Salmonids) and Trophic Models	M. Sigler, moderator
11:00	Q&A with Reviewers and Presenters: Application to Ecosystem Based Fishery Management	M. Sigler, moderator
12:00	Closing Remarks	M. Sigler
12:15	**Lunch <<End of Public Review>>**	
13:30	Reviewers: Closed Session	Conference Room